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(and they are of a very delicate nature), there is no perceptible effect of motion upon radiation.

In conclusion the authors desire to say that they are much indebted to Mr. Beckley, who not only invented the apparatus, but assisted at all the experiments, and without whom they could not have been performed in a manner so satisfactory. They are also indebted to Mr. Atkinson for his kindness in lending them a large gasometer, and to Mr. Browning and Mr. Ladd for exceedingly true aluminium and ebonite disks.

III. "On the Bones of Birds at different Periods of their Growth."

By JOHN DAVY, M.D., F.R.S., &c. Received October 23, 1866.

In this paper I beg to submit to the Royal Society the results of some further observations on the bones of birds, and more especially on those bones which in the adult contain air.

In offering them, I would wish them to be considered as a continuation of those communicated on a former occasion, and published in the Proceedings of the Society*.

In engaging in the inquiry I have had two objects chiefly in view: one to endeavour to determine whether at an early stage the bones, which at maturity contain air, differ essentially from those of birds which are then, and are permanently filled with marrow; another, to endeavour to ascertain in the instance of the former, the rate at which their early contents are absorbed, or an approximation to the time that air takes the place of the medulla.

The birds of the first kind subjected to observation have been the following: the common fowl, duck, goose, turkey, pheasant, partridge, grouse, rook, common crow, owl, sparrow-hawk, buzzard, blue tit; of the second kind, the woodcock, blackbird, water-ouzel, marten, swift, greenfinch, titlark, sparrow, stonechat, blackcap, yellow ammer, little sandpipe, canary.

I. *Of the Common Fowl*.—Of this bird I have examined the bones at different ages in a large number of instances. A few are selected as most characteristic:—

1. Of a foetal chick taken from the egg on the fourteenth day of incubation, the bones of the extremities were much advanced, the inferior more than the superior. Their epiphyses were almost gelatinous; but the shafts were partially ossified, and had already some firmness. In both the humeri and femora, medullary matter was found. It was of a red colour, and under the microscope exhibited the usual character of this tissue. Broken up, in each were seen numerous oil-globules, with which were mixed blood-corpuscles and other corpuscles of a smaller size, some circular, some of an irregular form.

* Vol. xiv. 337, 440, 475.

2. A chicken twenty-eight days old, reckoning from the time of hatching, was found dead on the 12th of January; during the preceding night there had been a severe frost. It weighed 10,275 grs.; one of its humeri in its moist state weighed 2·5 grs.; one of its femora 8 grs. In each of them a soft red medullary matter was detected, which, like the preceding, was composed of oil-globules, blood-corpuscles, and smaller colourless corpuscles or cells. The contents of the ulna and clavicular arch were similar, but in the latter the quantity of medullary matter was very minute.

3. Of a pullet three months old, which had been hatched on the 6th of April, and weighed, when examined, two pounds, the humeri thoroughly ossified, sank in water. From one of them, opened under water, a few air-bubbles only escaped, which came from its superior extremity. The canal of the bone, excepting the small portion from which the air proceeded, was full of red marrow of the usual appearance of medullary tissue, and with similar contents. A communication was found to exist by the air-foramen between the cancellated structure towards the head of the bone and the lung, through the adjoining air-sac.

4. Of another pullet of the same brood, but of more advanced growth, which, though three days younger when examined, weighed two pounds and three-quarters, the humeri sank in water, but in sinking maintained a perpendicular position. One of them laid open was found to contain in its inferior portion, to the extent of ·7 inch, marrow; in its superior, to the extent of 1·8 inch, air.

5. Of a pullet three months and eleven days old, which had been hatched on the 28th of May, the humeri floated in water. In one of them, laid open, a small portion of marrow was found in the cancellated structure of its distal extremity; and in this portion a conspicuous blood-vessel terminated,

6. Of a cock five months old, which weighed five pounds, the testes large, and abounding in sperm-cells and spermatozoa, the humeri contained only air.

II. *Of the Partridge*.—Of one shot on the 1st of September, which weighed 4136 grs., the humeri and femora sank in water; in sinking the distal extremity of the former reached the bottom first. From one of these, opened under water, a very little air escaped. The lining membrane was very vascular, and the lower one-fourth of the canal was full of blood of a dark colour, contained apparently in varicose vessels. Under the microscope, no oil-globules were distinguishable in the blood, only blood-corpuscles; nor in any part of the cavity were there found any remains of marrow.

2. Of another, shot on the same day, which weighed 5226 grs., the humeri swam in water, the femora sank. Air only was found in the former. On the lining membrane there were two or three delicate vessels containing florid blood. The femora were full of a reddish marrow.

3. Of another, shot on the 19th of October, which weighed 5432 grs.,

the state of the humeri and femora was very similar to that of the preceding. The humeri contained only air, the femora only marrow; the lining membrane of the former was finely vascular; the medullary tissue of the latter abounded in oil-globules and corpuscles suggestive of blood-corpuscles altered.

III. *Of the Pheasant*.—Of a female shot on the 9th of October, both the humeri and femora swam in water. Both contained air without any marrow. The former were perfectly white, and no vessels were visible in their lining membrane; the latter were of a reddish hue, and their lining membrane was beautifully vascular, the vessels delicately ramifying, of a bright florid hue, and anastomosing, and this throughout the whole of the circumference.

2. Of another female, shot on the 17th of October, the humeri contained only air, the femora air with a trace of marrow*. The latter were redder than the former, and their lining membrane was very vascular.

IV. *Of the Goose*.—Of one hatched in the spring, which, when examined on the 26th June, weighed eight pounds, the humeri sank in water. They were full of marrow of a light bright-red colour. The quantity collected from one of them was about 82 grs. It exhibited the usual character of medullary cellular structure, and was rich in oil, which in drying exuded copiously from it; but it contained comparatively few blood-corpuscles or blood-vessels, of which these corpuscles were the index.

2. Of another hatched on the 22nd of April, which on the 7th of August weighed nine pounds and a half, a humerus dissected out weighed 561 grs., was 7.5 inches in length, and its shaft between .4 and .5 inch in width. It sank in water. Its upper third portion was of a darker hue than its inferior two-thirds. The latter was full of a light-red marrow, abounding in oil. It owed its reddish hue to blood-vessels in the medullary structure. The former, entirely without air, contained a collection of blood-vessels resting on a cancellated structure. These vessels had the appearance of veins, seemed largely varicose, and were full of dark blood, which (examined whilst warm) was still fluid. Of the other wing, the humerus was somewhat different—the difference was in the superior portion. Although the bone sank in water, a little air was found in this portion, and the blood-vessels in it were less distended, and contained, instead of dark blood, aerated blood of a florid hue. The marrow, which occupied about two-thirds of the shaft, terminated abruptly superiorly, and there a pretty large blood-vessel united the two parts—the medullary and the varicose portions.

3. Of another hatched in the spring, examined on the 31st of October, the humeri contained only air. The lining membrane of its cavity was rich in blood-vessels.

* It was detected by washing out the cavity of the bone with a weak solution of salt. Oil-globules were found suspended in the solution.

4. Of the humerus of a goose hatched in the spring, weighing on the 2nd of November nine pounds, the canal was found full of air, with the exception of its inferior one-third; this contained marrow rich in oil. In one of several portions of it submitted to the microscope, a red vessel was seen containing granules and oil-globules. In one direction it ended abruptly, as if torn; in the other it was lost, as it were, by diffusion into, or blending with the cells of the medullary tissue. The upper portion of the marrow, it may be remarked, where it came in contact with the air, had, as in some other specimens, a rounded well-defined surface. In this instance no large blood-vessels were found in any part of the bone; and on the delicate membrane connecting the trabeculae of the cancellated structure, only a very few delicate vessels of a florid hue were to be seen.

5. Of a fifth, also hatched in the spring, when examined on the 20th of November, the humeri, like those of the last but one, were found to contain only air. Their lining membrane was very vascular and partially varicose.

V. *Of the Common Duck*.—Of a young drake hatched on the 26th of April, which when weighed on the 13th of August was four pounds, the humeri sank in water. They contained a light reddish marrow, and were entirely destitute of air.

2. Of two ducks of the same brood as the drake, the humeri, examined on the 15th of August, sank in water. Two-thirds of each were filled with marrow; one-third, the upper portion, with dark blood, seemingly in varicose vessels, which were connected with a light-coloured delicate membrane.

3. Of a duck, little more than one year old, the humeri contained only air.

VI. *Of the Red Grouse*.—Of one, which on the 12th of August was not fully fledged (it was shot for examination), the humeri contained air, the femora marrow.

2. Of another more advanced, shot on the 31st of August, weighing a pound and a quarter, the humeri contained air, the femora a little marrow, but more air, the former inferiorly.

3. Of a third, shot on the 28th of August, which weighed 8770 grs., the humeri were hollow, the femora partially so, a little reddish marrow only remaining, and this in their inferior extremity.

4. Of one shot on the 27th of August, which weighed 11,856 grs., and which, judging from its plumage, was probably a spring bird, both the femora and humeri swam in water and were free from any trace of marrow. The lining membrane of the cavities of the femora was beautifully vascular, the vessels of a florid hue from the well-aërated blood which they contained. The lining membrane of the humeri was similarly vascular, but in a less strongly marked manner.

VII. *Of the Rook*.—Of a young one not quite capable of flight, shot on the 11th of May, and which then weighed 6132 grs., the humeri sank

in water; they contained no air, but a soft marrow, of a blood-red colour. The bones were very vascular, and were easily cut.

2. Of another, shot on the 22nd of June, when capable of flight, though the quill-feathers of its wings were only partially hollow, its weight 5113 grs., the humeri sank in water in a perpendicular position. Of one which was examined, its inferior two-thirds were found full of a reddish marrow, its superior one-third of air. The proportion of oil seemed greatest in the distal part of the marrow. The bones were less vascular than those of the preceding, and of greater firmness.

3. Of a third, shot on the 23rd of June, then weighing 4982 grs., which, judging from the state of its feathers, its bursa Fabricii, ovary, and oviduct, had been hatched in the spring, the humeri were full of air without a vestige of marrow*.

VIII. *Common Crow*.—Of one shot on the 1st of June, then weighing 5402 grs., its quill-feathers not fully formed, the humeri sank in water, and contained only marrow.

2. Of another shot on the 21st of June, weighing 6533 grs., capable of flight, the humeri contained air. The lining membrane was very vascular.

IX. *Of the Tawny Owl*.—Of a young one, examined on the 21st of June, then weighing 4796 grs., its quill-feathers not fully formed, the humeri contained a very red marrow, and were entirely destitute of air.

2. Of one of uncertain but mature age, judging from its general appearance, and which weighed on the 8th of April 5776 grs., the humeri were full of air. There was also air in the scapular arch, and partially in the furcula, its proximate portion.

X. *Of the Sparrow-hawk*.—Of a young one, which on the 31st of July weighed 3686 grs., its sternum then only partially ossified, still flexible, the humeri were for the most part hollow; the little marrow they contained was confined to their distal portion. The same remark was applicable to the scapular arch. The femora contained even less marrow than the humeri; they were very nearly full of air.

XI. *Of the Buzzard*.—Of a young one taken from its nest on the 10th of June, when supposed to be about a fortnight old, then weighing 5293 grs., the quill-feathers of wings only sprouting, the bones generally were very vascular; the humeri and femora sank in water. Their ossification was much advanced, but the sternum was still cartilaginous. After drying, all the bones floated in water. The humeri and femora, now laid open, were found to contain a red matter lining but not filling the cavities, suggestive of its having been, in its moist state, a fluid or a semifluid. In this, its dried state, it was of a firm consistence. After soaking in water and trituration, it formed an emulsion, which, as seen under the microscope, was found to contain oil-globules and particles of different kinds. Digested and

* This bird, like most rooks, was infested with parasites, lice. They were plentiful even in the cavity of the wing quill-feathers. According to Dr. Gray, F.R.S., to whom I sent one, and who kindly gave me its name, it is a *Decophorus* (*D. atratus*).

beated in alcohol, it was partially dissolved, the solution becoming turbid on cooling. Evaporated, and as seen under the microscope, the residue, proportionally small, seemed to consist chiefly of fatty and oily matter (stearine and olein?), with some needle crystals.

XII. *Of the Blue Tit*.—Of a young one taken from the nest on the 31st of May; then weighing 28·5 grs., quite naked, except a few delicate fibre-like feathers on the head, some yolk still remaining in the abdominal cavity, the humeri were very small and pale, so small that no attempt was made to examine them, except by crushing. Comminuted with a few drops of solution of salt, and subjected to the microscope, there were seen mixed with the fragments of cartilage, blood-corpuscles and oil-like globules.

2. Of a young one, nearly fully fledged, which on the 3rd of August weighed 142 grs., the humeri sank in water, maintaining a perpendicular position. They were completely formed and well ossified. Excepting towards their inferior extremity they were white, there to a small extent they were red. The white portion, at least nine-tenths of the entire length, contained air; the red, not exceeding one-tenth, marrow which, as seen under the microscope, had all the character of medullary tissue and abounded in oil.

3. Of a third, shot in the same place as the preceding, and probably of the same brood, which on the 18th of August weighed 179·5 grs., the humeri floated in water, and were entirely full of air. The feathers of the abdomen were not fully formed, and the bursa Fabricii was much smaller than that of the preceding.

From these results, may not the following conclusions be drawn?

First, that at an early stage, and up to a certain period of growth, marrow exists in the bones specified, of all the birds first named; and that about the time of hatching the medullary tissue abounds less in oil or fatty matter than at a later, the proportion varying in different instances; least probably in birds of prey, such as the buzzard and owl; most in birds, the food of which is mostly vegetable, such as the goose.

Secondly, that the substitution of air for marrow in those bones which are eventually hollow, varies as to time in different species; is earlier in the rook, the crow, the grouse, the tit, than in the common fowl, duck, and goose, especially the latter; the exchange of one for the other having probably some relation to the time of taking wing and the use of the parts; and, in accordance, the humeri, except in the instance of the sparrow-hawk, seemed to have the marrow absorbed somewhat earlier than the femora. It may be conjectured that, like the residual yolk in the young bird, the marrow in the bones in question may serve in part as food, nourishing in the act of its removal.

Relative to the structure of the hollow bones, I have but a few words to offer.

In the humeri there is a peculiarity which may be deserving of mention. Towards the head of the bone, near the pneumatic foramen, the cancellated structure, connected more or less by a delicate membrane, performs the part of a valve, as indicated by its permitting a free access of air in one direction, but preventing in the other, its exit. This is clearly shown by the use of the blowpipe, and in no instance have I found an exception.

In the humerus of the common fowl, in three instances (a section of the bone having been made) the air has been found to enter from the pneumatic foramen by a small bony canal contiguous to the side of the bone, in length about $\cdot 6$ inch, in diameter about $\cdot 06$ inch *.

It is said that the trabeculæ, or minute columnæ in the cancellated structure of the hollow bones, are also hollow. In some of those of the humeri of the adult buzzard I have found a canal, but not in others; these were solid. Nor have I found them otherwise than solid in the humerus of the common fowl, goose, and turkey.

As to the bones of those birds of the second kind, in which the marrow is persistent through life, I may briefly remark that in them, as in the former, at an early period the marrow seems to be comparatively poor in oily matter; and that the earlier, the nearer the embryo state, the less is its degree of consistence, the nearer it is to a liquid, and the larger is the proportion of blood-corpuscles and of albuminous matter, and the smaller the proportion of the adipose.

When mature of growth, the bones of these birds appear to be richer in oily matter than those of the former permanently without air. Thus the tibia of the one kind in the dried state invariably sinks in water, whilst that of the first kind only partially sinks; the marrow in drying in the latter, from containing less oil, contracting more, and allowing of the entrance of air. In the radius and ulna the difference is less strongly marked; these bones in their dried state commonly sinking in water, even when belonging to birds of the first kind.

As regards the quality of marrow in the bones of different birds, the trials I have made have been very limited. I am disposed to infer from them that, besides differing, as in many instances it does in colour, it may differ also in composition, in the proportion of adipose matter and its kind, and in the proportion of albuminous matter; in some, as in the bones of the goose, oil most abounding; in others, as in those of the rook and buzzard, albuminous matter and fat of the stearine kind. Even in the bones of birds of the second kind, such as their long bones, there is a difference in this respect; of these, all that I have examined sink in water, with the exception of the femora, which only partially sink, the marrow in them being less rich in adipose matter, and consequently in drying contracting more, and, as before remarked, admitting more air.

* In one instance the same kind of structure was found in the femur of a pheasant.

As to the marked difference of birds of the two kinds in relation to the condition of their bones, the rationale is not very obvious. Perhaps an approximation to the truth, or to the probable, may be made by comparing the bones of birds of the two kinds, which are possessed of similar powers, the swift, for instance, and the buzzard, rivals in swiftness of flight and enduring power of wing. How different are their humeri! of the former, very short, strong, and compact, provided with firm and large processes for the attachment of muscles; in the latter, long, hollow, and light, and comparatively brittle, yet sufficiently firm to bear without fracture the muscles which act on them. Here, have we not after a manner a kind of substitution of qualities? great strength and extended surface in small space in the one, for lightness with greater length of leverage in the other. Further, the one kind of bone, that which contains marrow, being less brittle than that which contains air, and more yielding, may be less liable to fracture; a quality which, in the bird, before the ossification is complete, may be of essential service; so that, teleologically considered, it may perhaps serve to account for the bones which are eventually hollow having primarily marrow in place of air.

December 13, 1866.

WILLIAM BOWMAN, Esq., Vice-President, in the Chair.

Among the Presents announced were two manuscript volumes, by Solomon Drach, Esq., F.R.A.S., containing various Tables in Pure Mathematics, presented by the author.

The following communications were read:—

- I. "On Poisson's Solution of the Accurate Equations applicable to the Transmission of Sound through a Cylindrical Tube; and on the General Solution of Partial Differential Equations." By R. MOON, M.A., late Fellow of Queen's College, Cambridge. Communicated by Prof. J. J. SYLVESTER. Received November 14, 1866.

(Abstract.)

The pair of equations

$$\pm \frac{v}{a} = \log \frac{\rho}{D},$$

$$v = \phi \{ (v \pm a)t - q \},$$

which constitute Poisson's solution of the accurate equations applying to the transmission of sound through a cylindrical tube derived by La Grange's method, have long attracted the attention of mathematicians.